TREE FUND
Cultivating Innovation

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

3D Tree Mapping
Rethinking the DBH Tape

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The Need for Accurate Measurement

- E**cosystem services** (carbon sequestration and storage, stormwater attenuation, temperature regulation)[1]
- **Resource assessment** (value, biomass, volume, and size structure) depend on the ability to accurately determine tree size and structure[1]
- We measure 2D tree metrics
  - Height
  - DBH
  - Crown depth
  - Crown spread
- We can measure, often estimate 3D tree metrics
  - Volume

1 - Nowak, D.J., Crane, D.E., Stevens, J.C., Hoehn, R.E., Walton, J.T., Bond, J., 2008. A ground-based method of assessing urban forest structure and ecosystem services. Arboriculture and Urban Forestry 34, 347-358

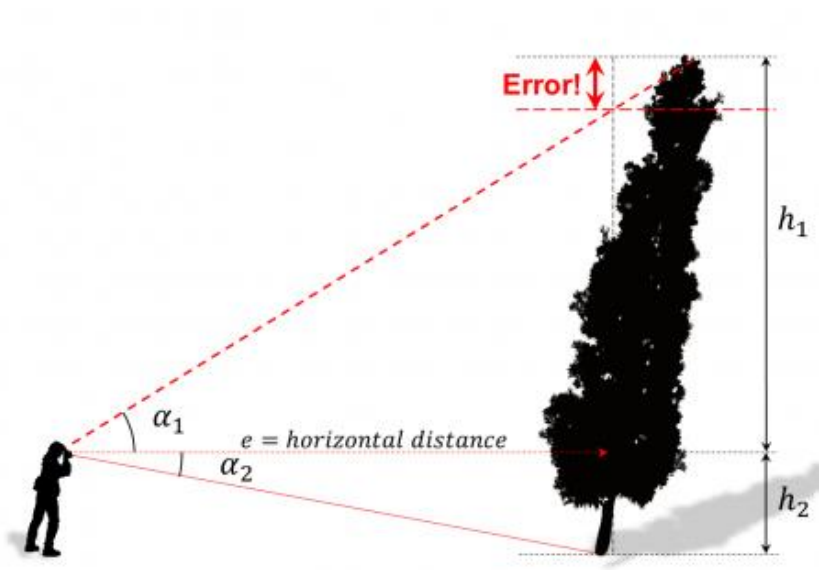
Current Measurement Techniques

- Diameter
  - Diameter tape
  - Caliper
- Height
  - Height pole
  - Clinometer
  - Hypsometer
  - Plumb line
- Volume
  - Xylometry (water displacement)

Error With Current Measurements

Height

- Hypsometers and clinometers assume that angles and distances are measured without error[2]
- User has correctly identified the highest part of the tree[2]
- Height error discrepancies can exceed 30%![2]

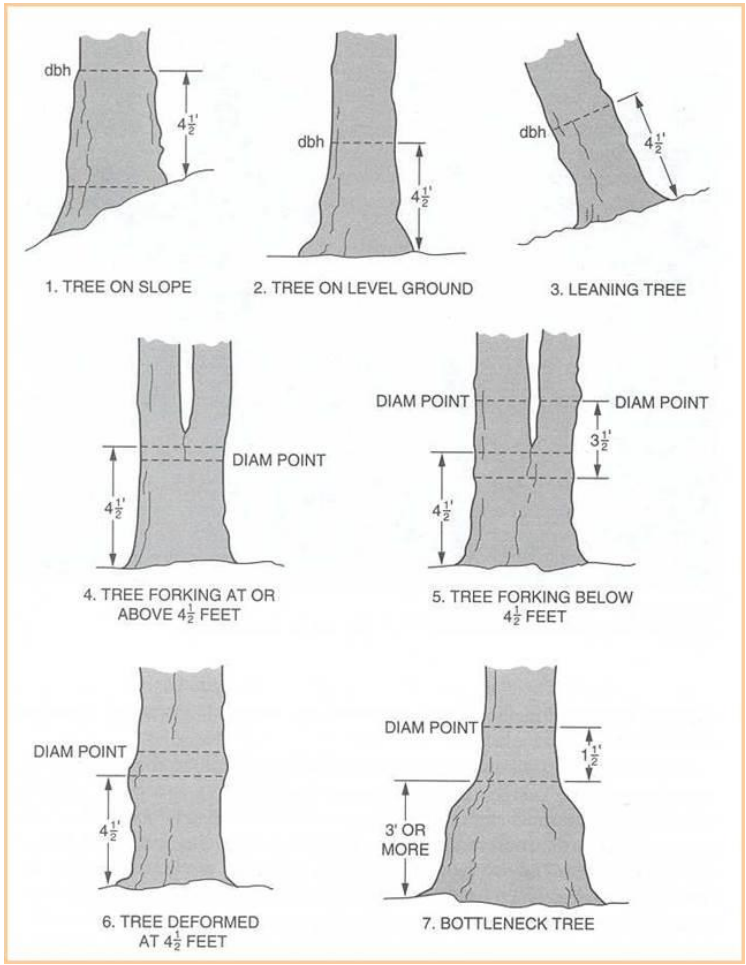


2 - Bragg, D.C., 2008. An improved tree height measurement technique tested on mature southern pines. Southern Journal of Applied Forestry 32, 38-43.

Error With Current Measurements

DBH

- Simple instrument
- Measurement height depends on country
- Tricky for trees on slopes, with multiple stems, or abnormalities
- Repeatability becomes problematic[3]



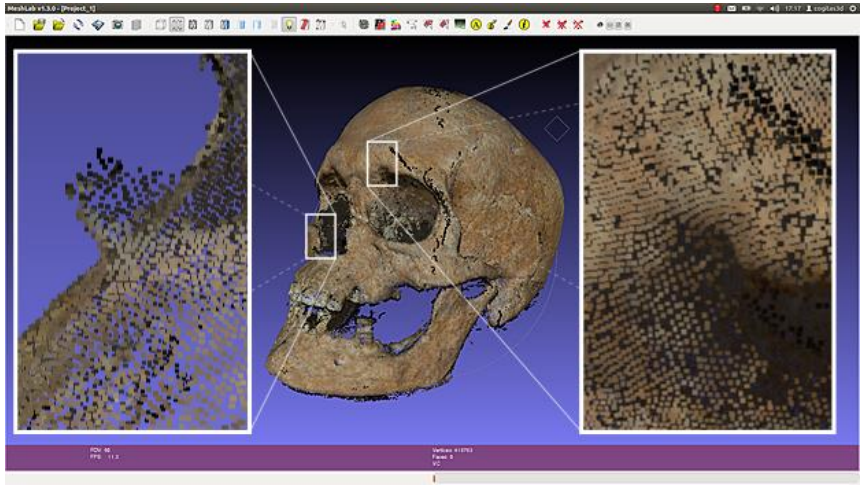
3 - Kitahara, F., Mizoue, N., Yoshida, S., 2010. Effects of training for inexperienced surveyors on data quality of tree diameter and height measurements. Silva Fennica 44, 657-667.

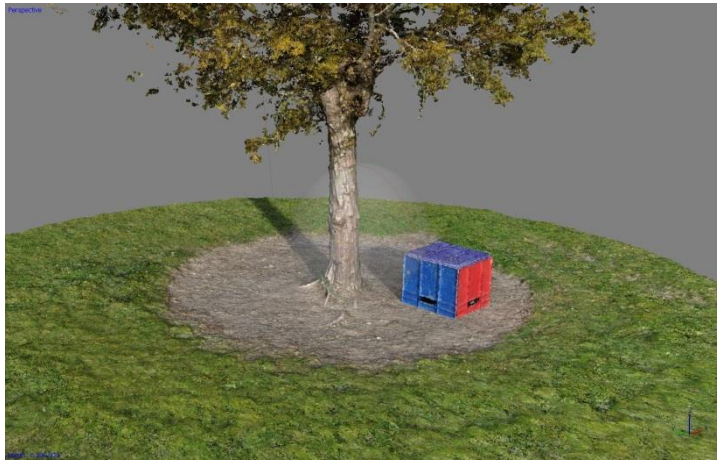
3D Modelling from Remote Sensing

- LiDAR (terrestrial laser scanning)
  - Produces point cloud based 3D model
  - Highly accurate
  - Costly ($5K – 250K)
  - Specialist knowledge
- SfM-MVS (structure-from-motion multi-view stereophotogrammetry)
  - Produces point cloud based 3D model
  - Cheap (Free - $1K)
  - Intuitive with simple software
  - Not well tested

Research Question

- Can SfM-MVS produce accurate estimates of 2D/3D tree metrics?





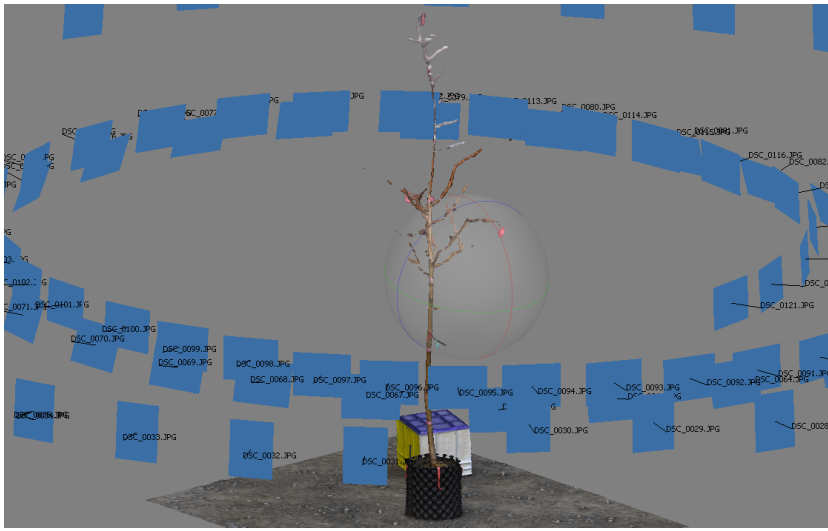
Study Details

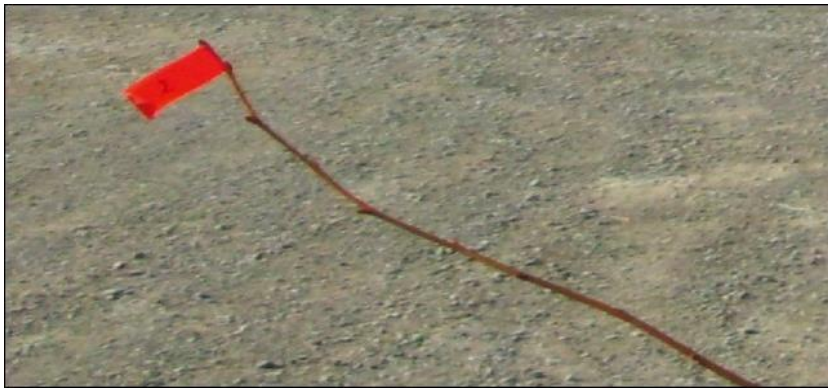
- Christchurch City Council nursery, NZ
- 30 trees in 25 L or 50 L plastic pots
  - 12 large-leaved linden (*Tilia platyphyllos*), 10 field maple (*Acer campestre*), 5 walnut (*Juglans regia*) and 3 red maple (*Acer rubrum*)
- Photographed before/after leaf fall

Ground Truth Data	Units	Mean	SD	Max	Min
Height	m	2.98	0.716	4.53	1.64
Average Crown Spread	m	1.14	0.446	3.06	0.52
DBH	mm	19.3	4.5	28	5

Methods – Photography

- Any camera will do
  - Body: Nikon D5000
  - Lens: AF-S NIKKOR 35 mm
    - Avoid distortion
  - Tradeoff between pixel density and processing speed
- 150-180 photos per tree
- Lots of overlap needed
- Red tape placed at measurement points





Methods – Processing

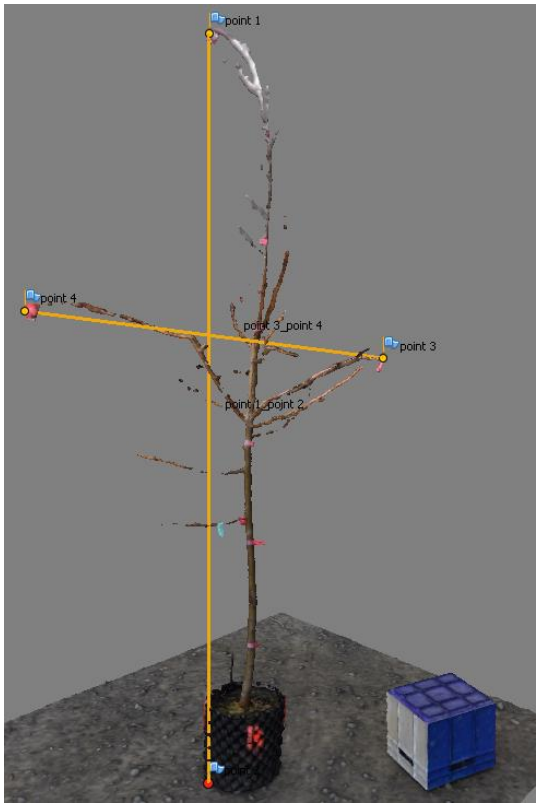
- Software: Agisoft Photoscan Professional
- Simple GUI
- 3 easy steps
  - Image alignment → sparse point cloud
    - Pixel matching
  - Dense point cloud
  - Mesh surface model

3D Model Measurements

Point markers created for 2D estimates

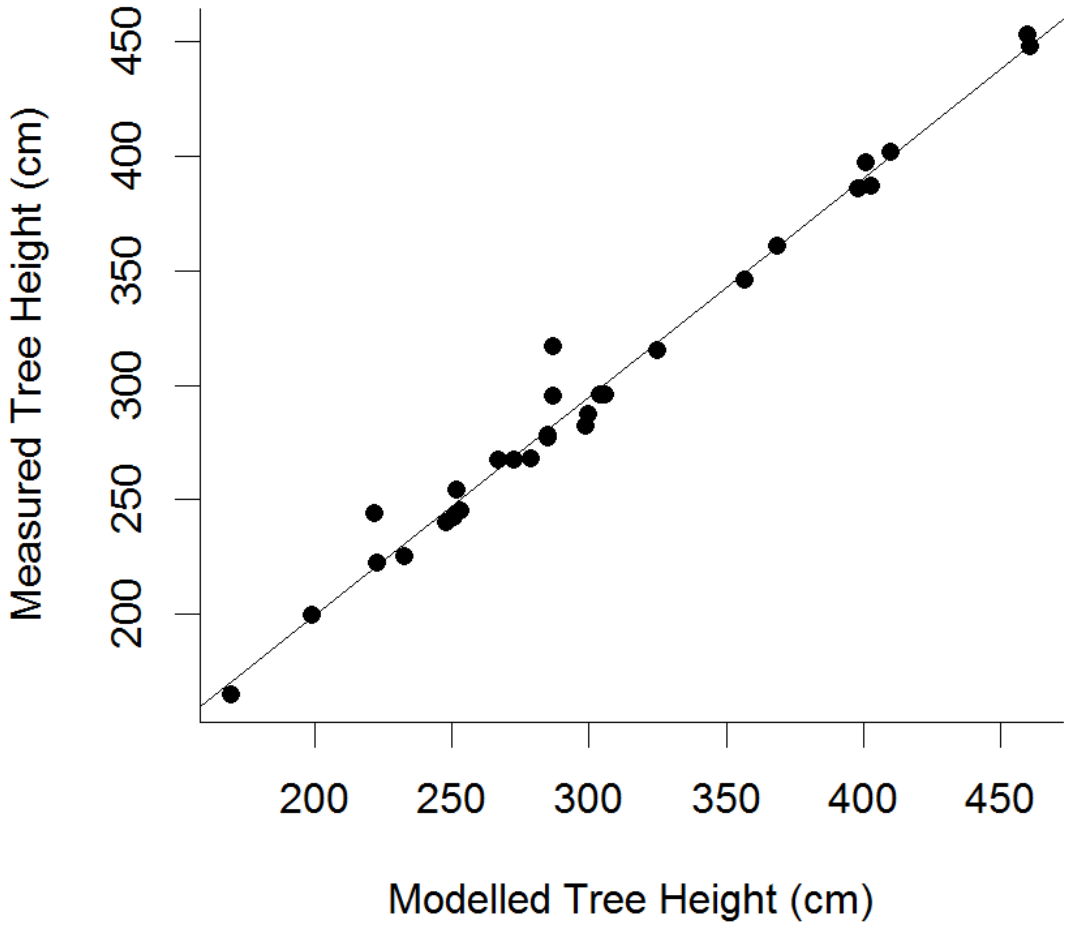
Water-tight model for 3D estimates

Aspatial 3D models need calibration



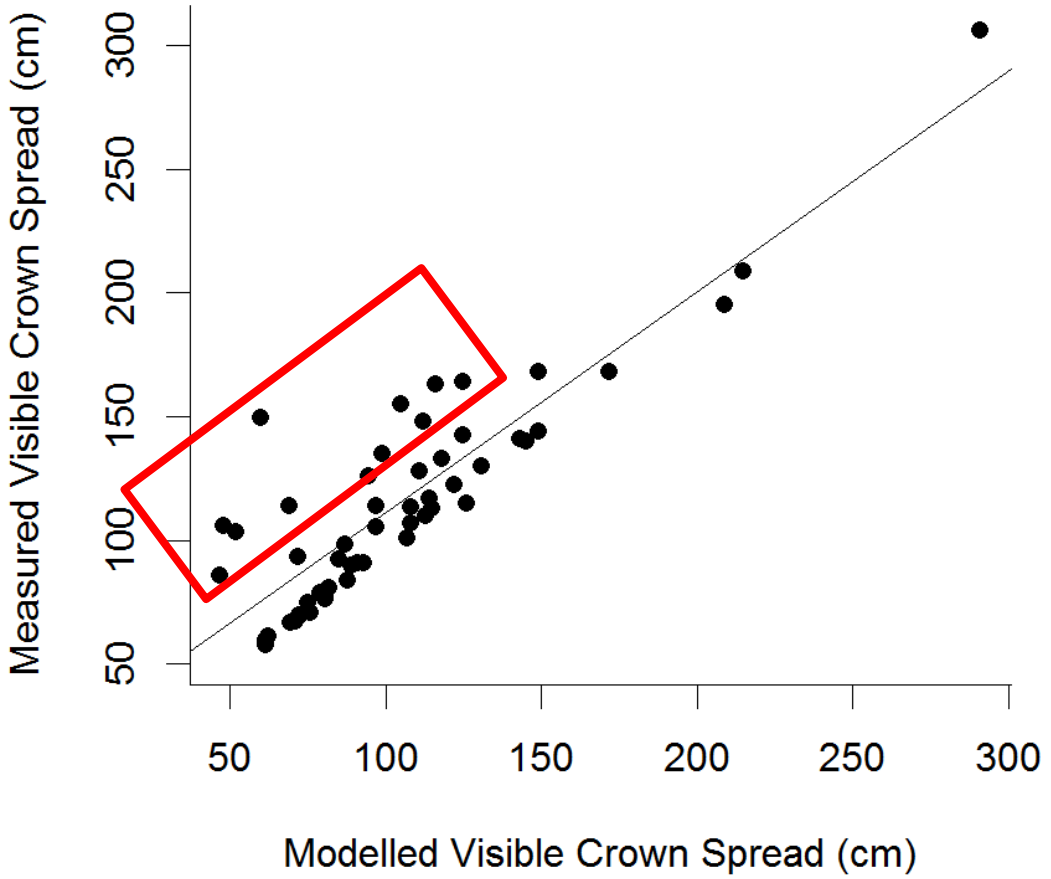
Result - Height

R^2	0.98
RMSE	11.1 cm (3.7%)
Bias	5.2 cm (1.7.%)

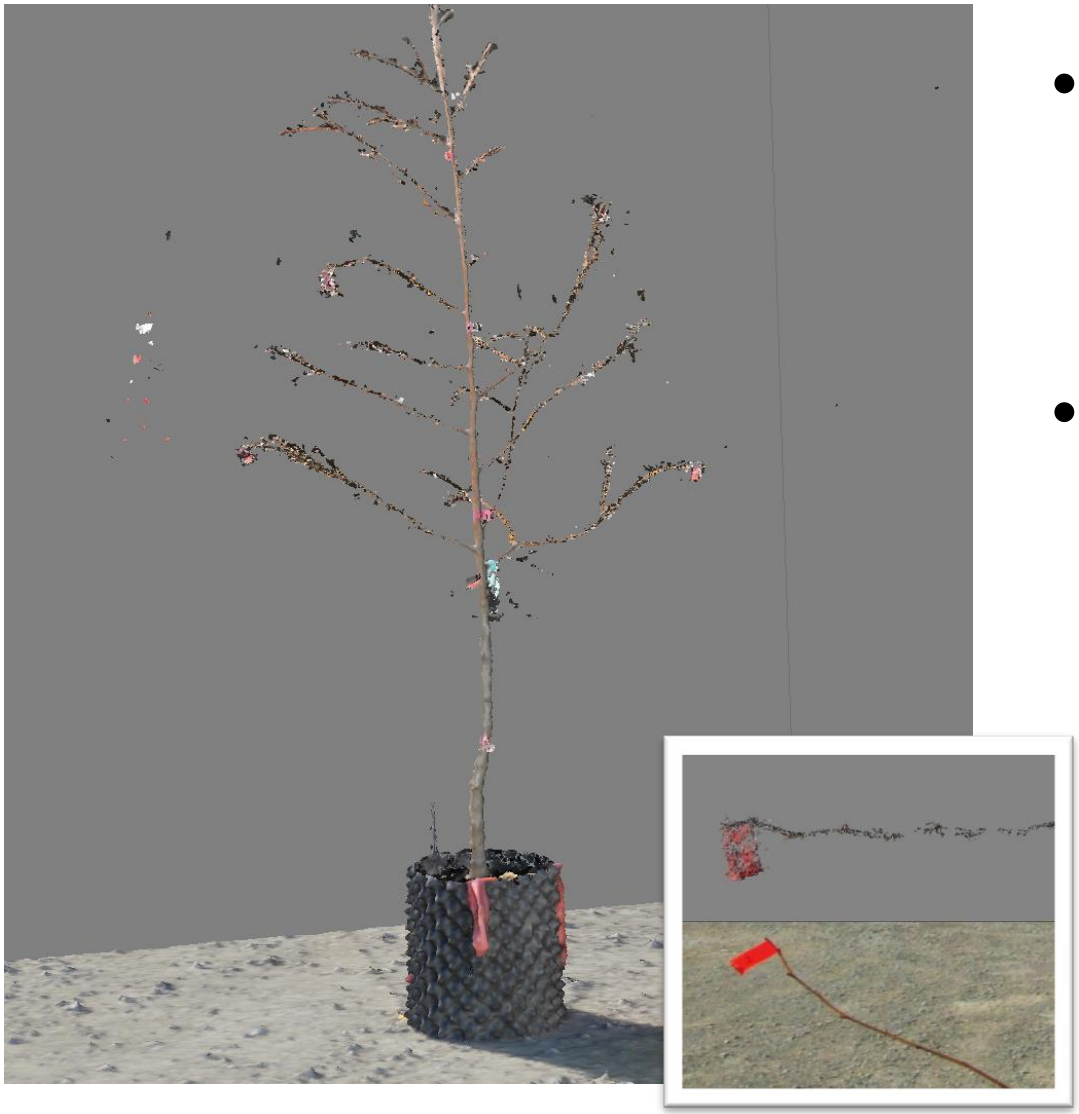


Result – Visible Crown Spread

R^2	0.78
RMSE	23.8 cm (21.1%)
Bias	-10.7 cm (-9.5%)



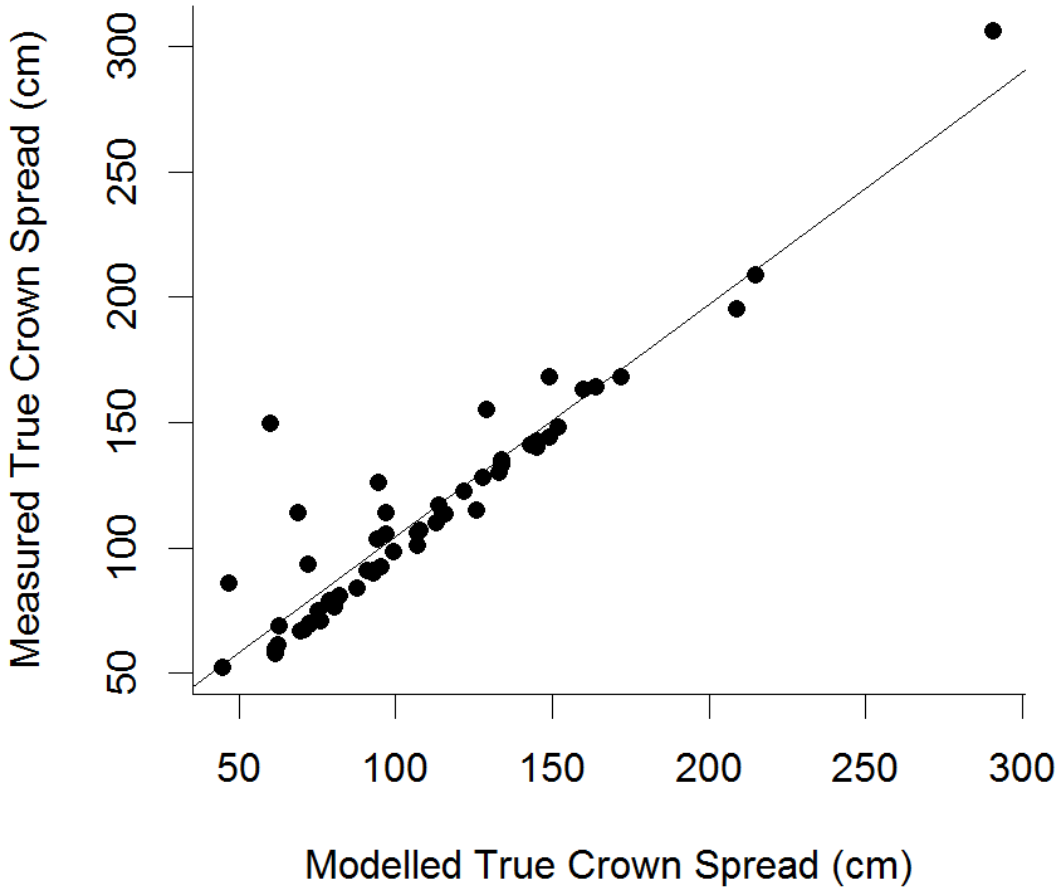
Issue with Visible Crown Spread



- Visible crown spread in 3D model does not represent reality
- Measurements made based on visible extent of branches, not true extent
  - Hence the red tape to measure true crown spread

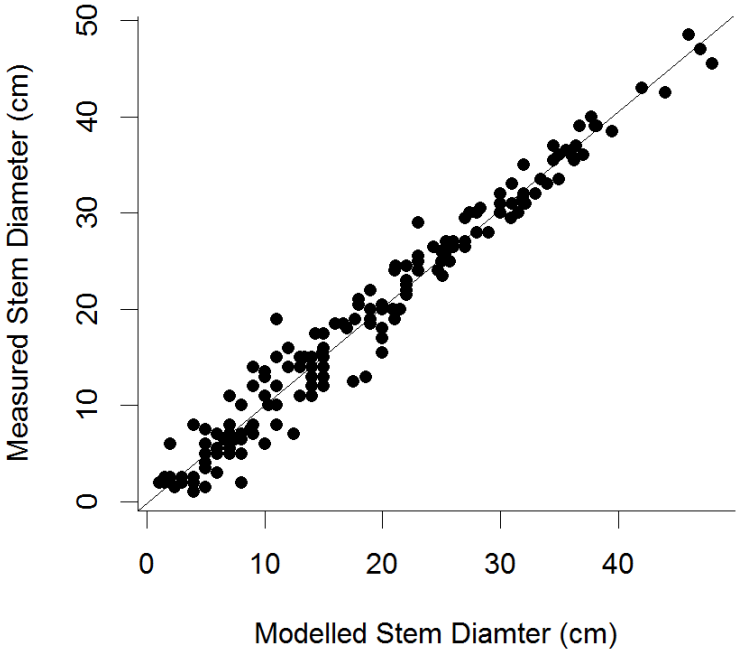
Result – True Crown Spread

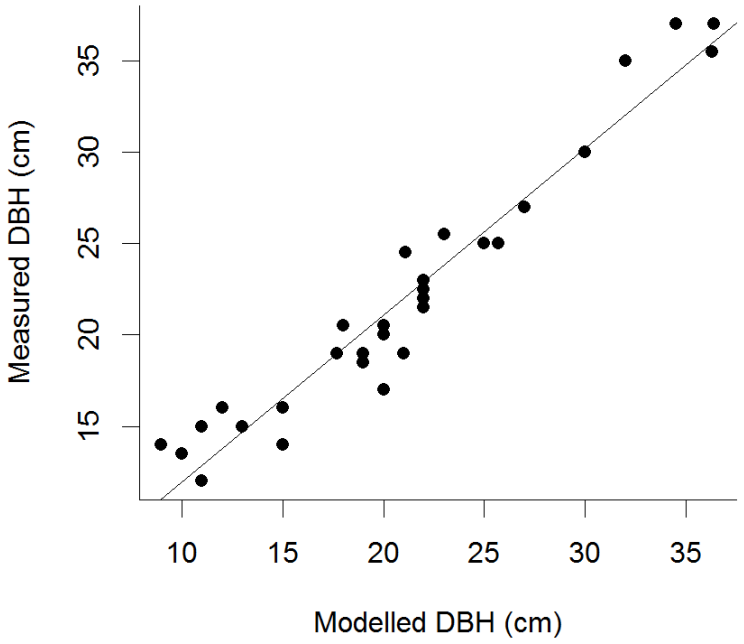
R^2	0.87
RMSE	16.6 cm (14.8%)
Bias	-3.9 cm (-3.5%)



Result – Stem Diameter

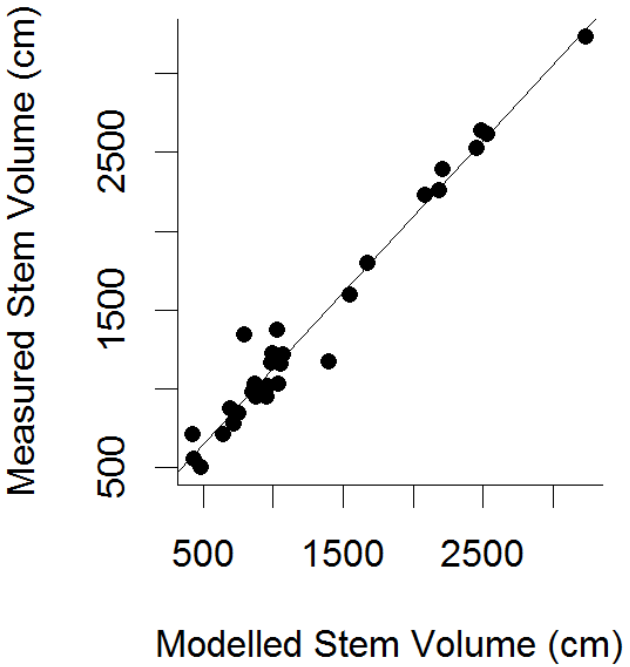
	Stem Diameter$_{combined}$	DBH
R^2	0.97	0.94
RMSE	2.1 mm (11.9%)	2.1 mm (9.6%)
Bias	-0.2 mm (-0.9%)	-0.99 mm (-4.5%)

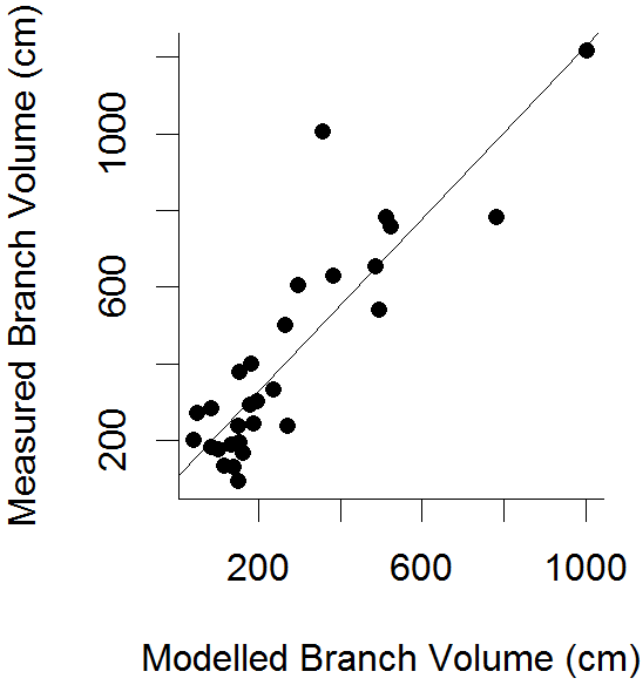




Result - Volume

	Stem Volume	Branch Volume
R^2	0.97	0.76
RMSE	173.72 cm^3 (12.3%)	195.2 cm^3 (47.5%)
Bias	-115.5 cm^3 (-8.2%)	-138.6 cm^3 (-33.8%)

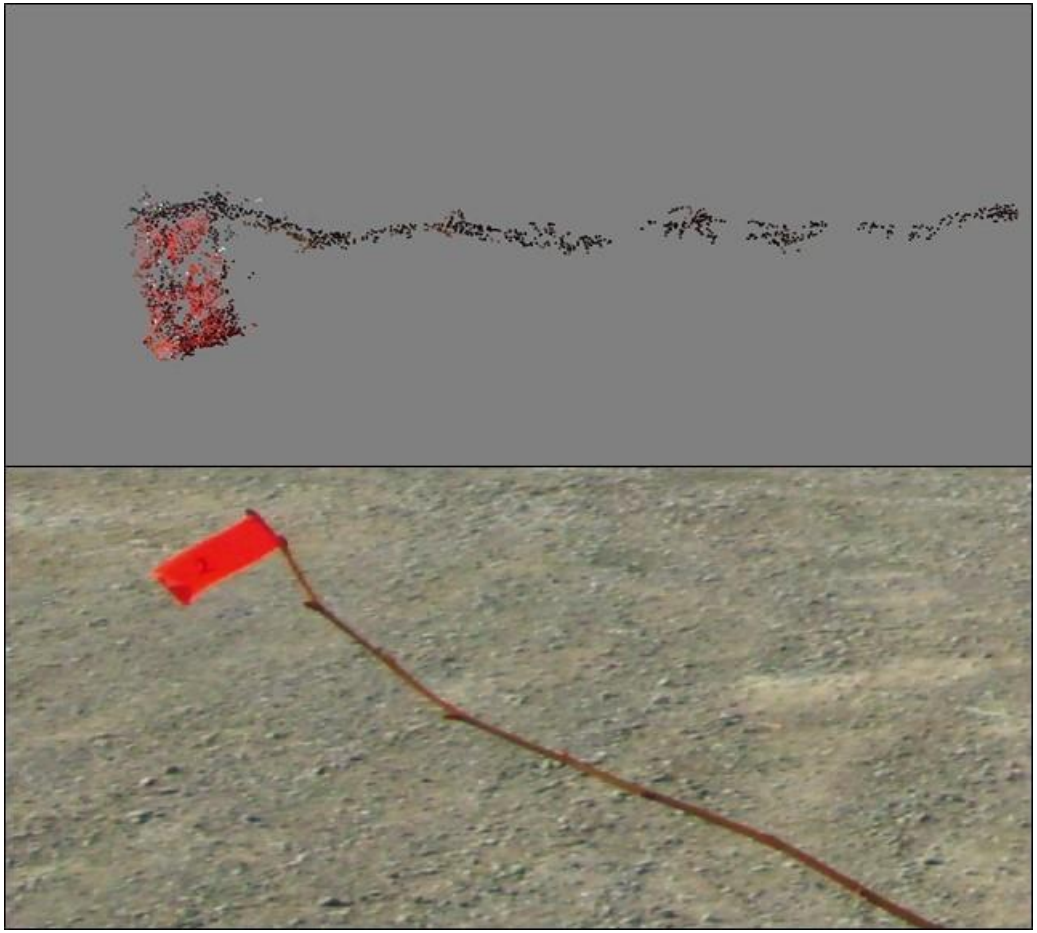




Result Summary

Metric	RMSE (%)	Bias (%)
Height	3.7	1.7
True Crown Spread (cm)	14.8	-3.5
Visible Crown Spread (cm)	21.1	-9.5
DBH (mm)	9.6	-4.5
Combined Stem Diameters (mm)	11.9	-0.9
Stem Volume (cm^3)	12.3	-8.2
Branch Volume (cm^3)	47.5	-33.8
Total Volume (cm^3)	18.5	-14.7

Known Issue – Slender Branches



- Slender branches not captured by a sufficient number of pixels
- Tape impractical
- Less of an issue for larger trees

Known Issues – Light and Wind

- Shadow prevents pixel matching
- 3D model quality affected
- Volume most severely affected
- Shoot in diffuse light and over a short time period

- Wind creates blur prevents pixel matching

Conclusions

- Don’t throw away that DBH tape yet
- But, don’t bury your head in the sand
  - RS technologies are complementing and replacing traditional inventory in natural and plantation forest management

Acknowledgements

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- We appreciate the technical help of Mr. Lachlan Kirk and Mr. Paul Bealing who provided support throughout this research.